

**RTCA Special Committee 186, Working Group 3**

**ADS-B 1090 MOPS**

**Meeting #7**

**Extended Squitter Interference Test Data**

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SUMMARY
The FAA Technical Center (ACT-350) has conducted the Enhanced Surveillance Processing Test Procedures as defined in 2.4.4.4 (1090-WP-6-04) utilizing the RF Measurement Facility and the associated enhanced reception implementations. This paper contains the results of these tests as assigned by action item 5-7 to be used as input to provide the required performance for the enhanced surveillance processing techniques in 2.4.4.4.

## Introduction

The Enhanced Surveillance Processing Test Procedures, subparagraph 2.4.4.4.3, “Data Block Tests” and subparagraph 2.4.4.4.6 “Combined Preamble and Data Block Tests with ATCRBS Fruit” were conducted using the Radio Frequency Measurement Facility (RMF) / Data Link Test and Analysis System (DATAS) configuration described in 1090-WP-5-09. The data is presented in this working paper to provide input to assist WG-3 with determining the minimum required reception probability for the respective number and types of fruit.

There are currently three enhanced reception techniques that have been implemented to detect and decode Extended Squitters with the RMF. The techniques are: (1) the RMF Gold Standard, which is a multiple sample method that uses sample pattern look-up tables, (2) the enhanced Center Sample method, and (3) an alternative Multiple Sample method that does not require pattern lookup tables. These methods are described in detail in 1090-WP-3-08 and 1090-WP-5-07. Data is presented in this paper utilizing all three methods.

## 1.0 Signal Sources

This section will directly relate the test configuration that was used to conduct these tests with the requirements established in 1090-WP-6-04, subparagraph 2.4.4.4.2.

### 1.1 ATCRBS Fruit Signal Source

Five (5) RF sources shall be provided that are capable of generating ATCRBS 14-pulse replies. Each fruit source shall be capable of the following:

- A. The waveform shall consist of bracket pulses and an average of five data pulses. The data content of the fruit reply shall be pseudo randomly varied each time a fruit reply is generated. The data pulses shall be uniformly pseudo randomly distributed across the 12 data bit positions (the X pulse position shall not be used). **The test configuration complies with this requirement.**
- B. Each fruit source shall be able to generate an ATCRBS reply at a received power level of at least 12 dB above MTL. All five fruit sources shall operate at the same power level, plus or minus 1 dB. **The test configuration complies with this requirement. Extensive calibration of all signal sources was conducted and all sources relative amplitudes were verified to be well within the plus or minus 1 dB limitation.**
- C. The fruit sources should be able to sustain a repetition rate of at least 100 replies per second. **The test configuration complies with this requirement.**

- D. The signals for each of the fruit sources shall be non-coherent with any of the other fruit sources and the Extended Squitter signal source (2.4.4.4.2.3). **The Extended Squitter signal source was non-coherent with any of the fruit sources, however, the test configuration used a total of 3 fruit sources. The test steps that required 4 and 5 ATCRBS fruit had 1 or 2 of the RF sources provide 2 fruit signals.**
- E. The leading edge of the P1 pulse of the Extended Squitter waveform shall be defined as  $t=0$ . The timing of the generation of the beginning of the F1 pulse of each fruit reply shall be controllable to be uniformly pseudo randomly distributed over one of the following intervals (depending on the test):

+8 to +100 microseconds (Extended Squitter data block with ATCRBS fruit test)

-20 to +100 microseconds (Combined Extended Squitter preamble and data block with ATCRBS fruit test)

**The test configuration complies with this requirement.**

- F. The pseudo random timing of the generation of the fruit replies from each fruit source shall be independent of the timing of the other fruit sources. **When conducting tests with three or less ATCRBS fruit, the test configuration was compliant with this requirement. However, for 4 and 5 fruit tests, when using any fruit source to generate 2 fruit replies, that source was set to randomly distribute 1 fruit within each half of the total range defined in 1.1.5.**

## 1.2 Mode S Fruit Signal Source

The test configuration was fully compliant with all requirements of section 2.4.4.4.2.2 for the Mode S fruit signal source. Therefore, the individual requirements will not be listed here.

### 1.3 Extended Squitter Signal Source

One RF source shall be provided that is capable of generating a 112-bit Extended Squitter transmission with no more than 1 dB droop as follows:

- A. The Extended Squitter power level shall be adjustable relative to the fruit power level over the following steps (in dB): -12, -8, -4, 0, +4, +8, +12. **The test configuration complies with this requirement. The actual power levels used were as follows:**

Relative Level	-12	-8	-4	0	+4	+8	+12
Extended Squitter Amplitude (DBM)	-62	-58	-54	-50	-46	-42	-38
ATCRBS Fruit Amplitude(DBM)	-50	-50	-50	-50	-50	-50	-50
Mode S Fruit Amplitude (DBM)	N/A	N/A	N/A	-50	-50	-50	-50

- B. The Extended Squitter signal source should be able to sustain a squitter rate of at least 100 squitters per second. **The test configuration complies with this requirement.**
- C. The contents of the Extended Squitter transmission shall consist of the five-bit DF field set to 17, an 83-bit field that is set pseudo randomly for each Extended Squitter transmission, and a 24-bit PI field appropriate for the content of this transmission. **The content of the Extended Squitter signal consists of DF 17 and DF 18 Extended Squitters. Other than the DF field the remainder of the message content is pseudo-random. The 51-bits following the 5-bit DF field are random. The next 32 bits contain address parity derived from the first 56 bits, and the last 24 bits contain address parity derived from the first 88 bits.**
- D. Provision shall be made to record the contents of each Extended Squitter transmission. *NOTE: This information is required to check for undetected errors.* **The contents of each Extended Squitter was not recorded, instead the combination of the 24-bit parity check and the additional 32-bit parity check was used to test for undetected errors.**

In the following test data, there were 1000 trials executed per test point unless otherwise noted. A test point consists of a specified number of fruit at a given relative amplitude.

## 2.0 Data Block Tests with ATCRBS Fruit (2.4.4.4.3.1)

Tests were conducted to inject Extended Squitter messages with ATCRBS fruit according to 1090-WP-6-04 subparagraph 2.4.4.4.3.1, with the test configuration as defined in section 1.0 above. The tests were conducted with each of the three enhanced reception techniques. Table 2-1 below shows the average reception probability for the 3 enhanced reception methods with 1 through 5 ATCRBS fruit. Each value is the average of all 7 relative amplitudes.

Number of Fruit	1	2	3	4	5
Gold Standard	95.94	89.24	79.51	71.84	63.36
Center Sample	96.46	67.07	49.63	41.36	36.86
Multiple Sample	99.91	94.17	82.83	70.17	59.2

Table 2-1 Data Block Tests with ATCRBS Fruit - Average Reception Probability

The data in Table 2-1 corresponds to Table 2.4.4.4.3.1 in the proposed Enhanced Surveillance Processing Test Procedures. This data is intended to be used by WG-3 to set the required minimum probabilities. The Multiple Sample technique performs the best with 3 or less fruit, and the Gold Standard performs the best with 4 or more fruit. Figure 2-1 shows a graphical representation of the same data. There were no occurrences of undetected errors during these tests.

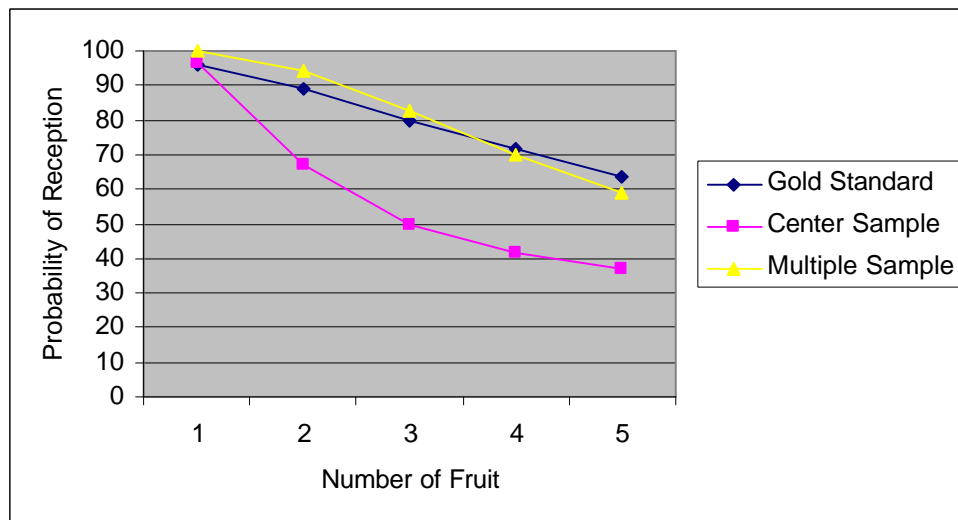


Figure 2-1 Average Reception Performance of the 3 Enhanced Reception Techniques – Data Block Tests with ATCRBS Fruit

Table 2-2 shows the Data Block Tests with ATRBS Fruit test data for the Gold Standard reception technique expanded to include the data for each relative amplitude. Figure 2-2 is a graphical representation of the same data.

Number of Fruit	1	2	3	4	5
S/I = -12	96.9	90	74.5	61.4	48.6
S/I = -8	98.1	91	79.6	70.5	53.5
S/I = -4	89.8	79.3	65.4	53.1	43.7
S/I = 0	86.9	67.7	47.2	31.9	21.7
S/I = +4	99.9	96.7	90.1	86.2	76.2
S/I = +8	100	100	99.8	99.8	99.8
S/I = +12	100	100	100	100	100
Average Reception Probability	95.94	89.24	79.51	71.84	63.36

Table 2-2 Data Block Tests with ATRBS Fruit – Gold Standard Reception Technique

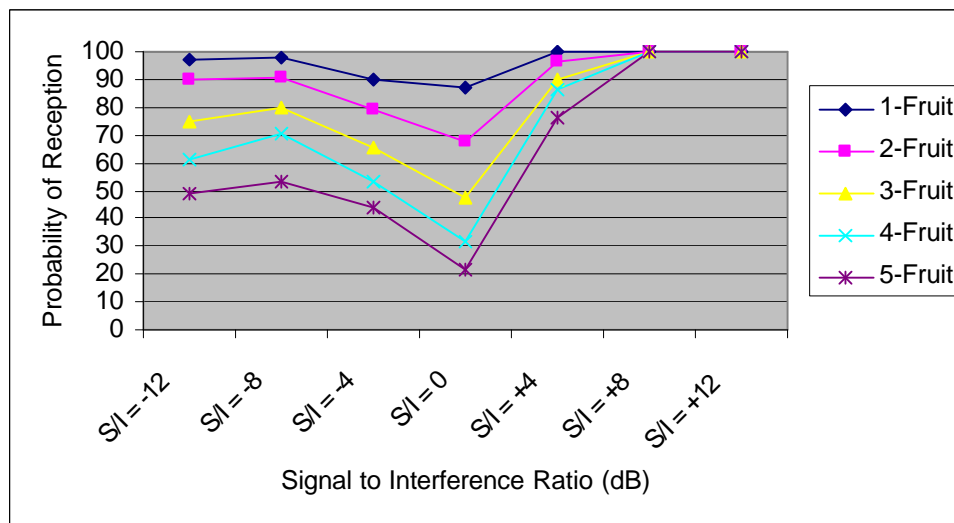


Figure 2-2 Data Block Tests with ATRBS Fruit – Gold Standard Reception Technique

Table 2-3 shows the Data Block Tests with ATCRBS Fruit data for the Center Sample reception technique expanded to include the data for each relative amplitude. Figure 2-3 is a graphical representation of the same data.

Number of Fruit	1	2	3	4	5
S/I = -12	83.4	48.5	18.9	3.9	0.7
S/I = -8	92.9	51.3	20.6	5.8	1.2
S/I = -4	99.5	42.5	11.3	3.1	0.8
S/I = 0	99.4	28.5	6.1	0.4	0
S/I = +4	100	98.7	90.5	76.4	55.4
S/I = +8	100	100	100	99.9	99.9
S/I = +12	100	100	100	100	100
Average Reception Probability	96.46	67.07	49.63	41.36	36.86

Table 2-3 Data Block Tests with ATCRBS Fruit – Center Sample Reception Technique

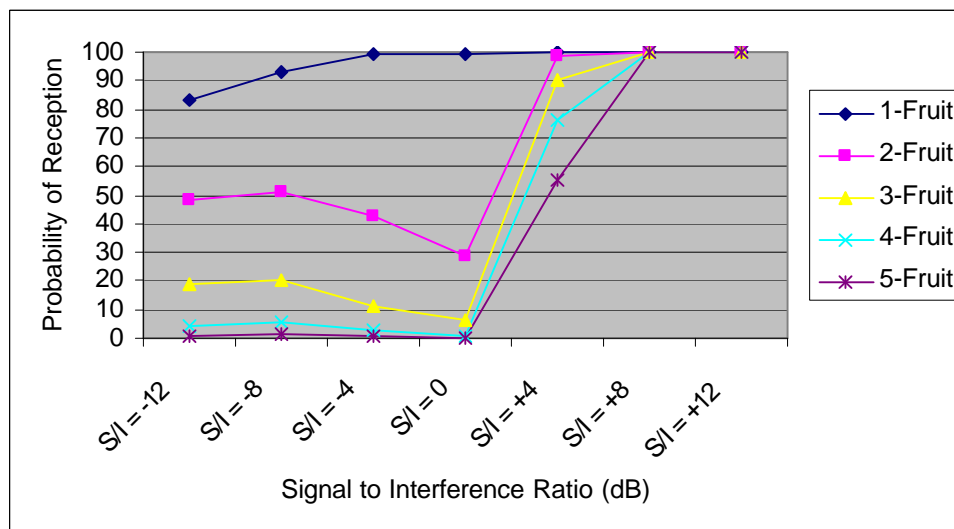


Figure 2-3 Data Block Tests with ATCRBS Fruit – Center Sample Reception Technique

Table 2-4 shows the test data for the Multiple Sample reception technique expanded to include the data for each relative amplitude. Figure 2-4 is a graphical representation of the same data.

Number of Fruit	1	2	3	4	5
S/I = -12	99.8	100	77.9	51.4	31.5
S/I = -8	99.7	97.7	88.2	68.2	46.7
S/I = -4	100	98.9	88.9	72.3	52.9
S/I = 0	99.9	63.2	27.4	9.3	3.7
S/I = +4	100	99.4	97.4	90	79.6
S/I = +8	100	100	100	100	100
S/I = +12	100	100	100	100	100
Average Reception Probability	99.91	94.17	82.83	70.17	59.2

Table 2-4 Data Block Tests with ATCRBS Fruit – Multiple Sample Reception Technique

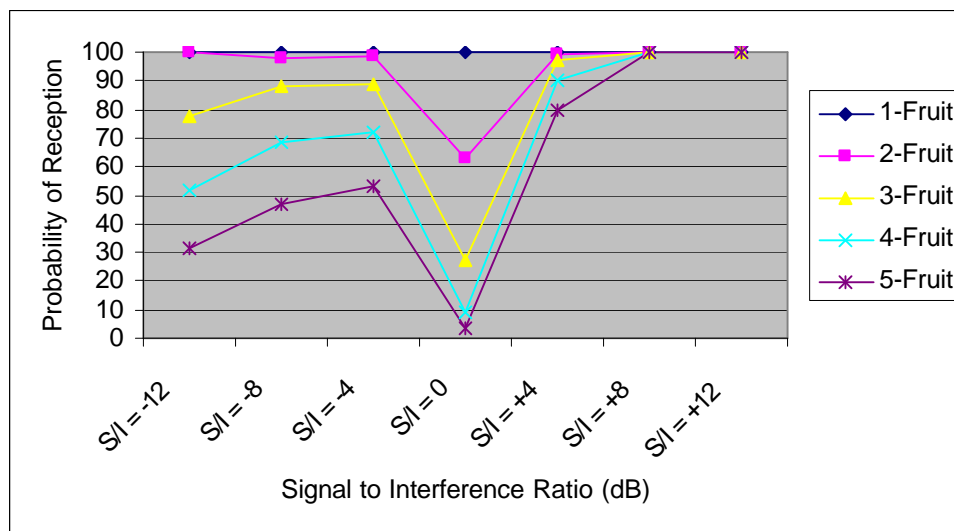


Figure 2-4 Data Block Tests with ATCRBS Fruit – Multiple Sample Reception Technique

### 3.0 Data Block Tests with Mode S Fruit (2.4.4.4.3.2)

Tests were conducted to inject Extended Squitter messages with Mode S fruit according to 1090-WP-6-04, subparagraph 2.4.4.4.3.2, with the test configuration as defined in section 1 above. The tests were conducted with each of the three enhanced reception techniques. Table 3-1 shows the reception probability for the 3 enhanced reception methods for each of the 4 relative amplitudes.

Relative power, (S/I) dB	0	+4	+8	+12	Average
Gold Standard	1.3	29.2	100	100	57.63
Center Sample	0	21.5	86.6	100	52.03
Multiple Sample	0	26.9	100	100	56.73

Table 3-1 Data Block Tests with Mode S Fruit



The data in Table 3-1 corresponds with Table 2.4.4.4.3.2 in 1090-WP-6-04. There were no real occurrences of undetected errors recorded during the tests with Mode S fruit. However, there were a few near misses. Out of the 36,000 trials for both the Data Block tests with 4 dB steps and 1 dB steps there were about 6 occurrences of 112-bit Mode S decodes that passed the 24-bit parity check that also failed the 32-bit parity check. It appeared the false messages were the result of a false trigger from a combination of the Extended Squitter and the Mode S fruit. In each case, the resulting DF code was less than 16 with a long message, which is currently illegal.

The tests were repeated between relative amplitudes of 0 and +8 to get a more viewable probability curve. The data is presented in Table 3-2 and Figure 3-1.

Relative power, (S/I) dB	0	+1	+2	+3	+4	+5	+6	+7	+8
Gold Standard	1.4	1.5	2.4	2.4	29.5	46.6	85.5	99.6	100
Center Sample	0	0.4	0.8	1.7	18.2	27.6	44.3	62.3	92.3
Multiple Sample	0.1	0	0.1	0.9	26	47.4	83	99.2	100

Table 3-2 Data Block Tests with Mode S Fruit – 1 dB Steps

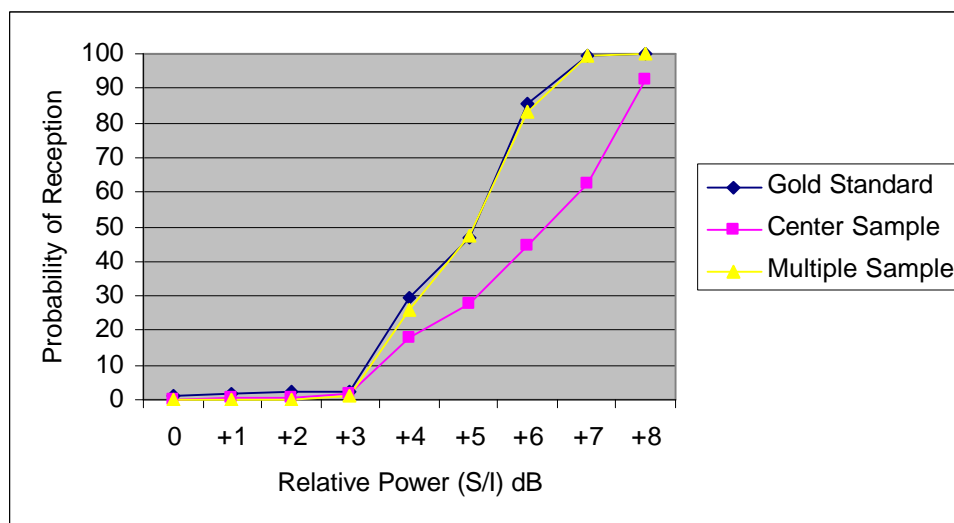


Figure 3-1 Data Block Test with Mode S Fruit – Reception Probability Curves

#### 4.0 Combined Preamble and Data Block Tests with ATCRBS Fruit (2.4.4.4.6)

The combined preamble and data block tests with ATCRBS fruit were conducted according to 1090-WP-6-04, subparagraph 2.4.4.4.6, with the test configuration as defined in section 1 above. The tests were conducted with each of the three enhanced reception techniques. Table 4-1 shows the average reception probability for the 3 enhanced reception methods with 1 through 5 ATCRBS fruit. Each value is the average of all 7 relative amplitudes.

Number of Fruit	1	2	3	4	5
Gold Standard	96.44	90.6	84.47	77.37	69.69
Center Sample	96.87	72.83	57.7	46.53	40.79
Multiple Sample	99.76	94.67	87.14	77.5	68.97

Table 4-1 Combined Preamble and Data Block Tests with ATCRBS Fruit - Average Reception Probability

The data in Table 4-1 corresponds to Table 2.4.4.4.6.1 in the proposed Enhanced Surveillance Processing Test Procedures. The Multiple Sample technique performs the best with 4 or less fruit, and the Gold Standard performs slightly better with 5 fruit. Figure 4-1 shows a graphical representation of the same data. There were no occurrences of undetected errors during these tests.

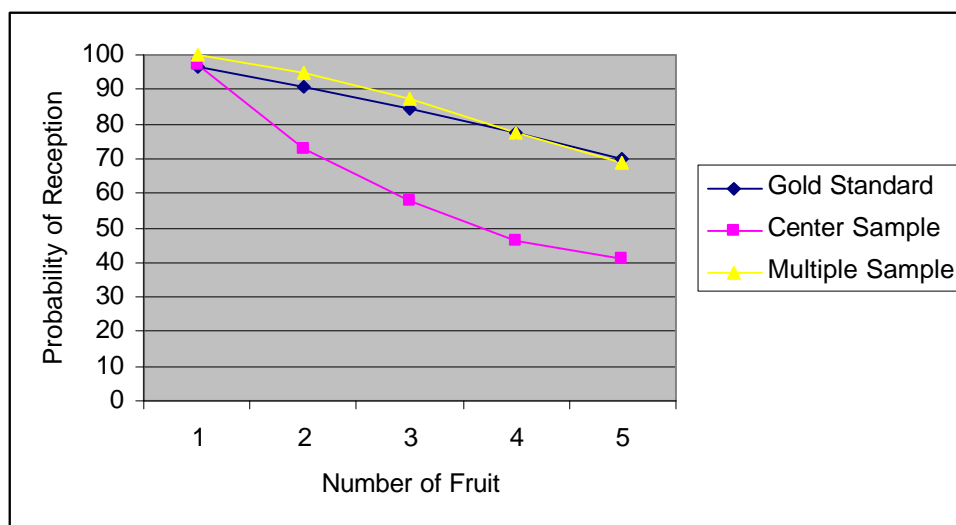


Figure 4-1 Average Reception Performance of the 3 Enhanced Reception Techniques – Combined Preamble and Data Block Tests with ATCRBS Fruit

Table 4-2 shows the Combined Preamble and Data Block Test data for the Gold Standard reception technique expanded to include the data for each relative amplitude. Figure 4-2 is a graphical representation of the same data.

Number of Fruit	1	2	3	4	5
S/I = -12	97.6	92.3	80.7	72.1	57.6
S/I = -8	98.7	91.8	85.9	76.3	66.7
S/I = -4	91.9	83	71.7	61.7	51
S/I = 0	87.1	69	59.2	43.2	30.1
S/I = +4	99.8	98.1	93.9	88.7	82.8
S/I = +8	100	100	99.9	99.6	99.6
S/I = +12	100	100	100	100	100
Average Reception Probability	96.44	90.6	84.47	77.37	69.69

Table 4-2 Combined Preamble and Data Block Tests with ATCRBS Fruit – Gold Standard Reception Technique

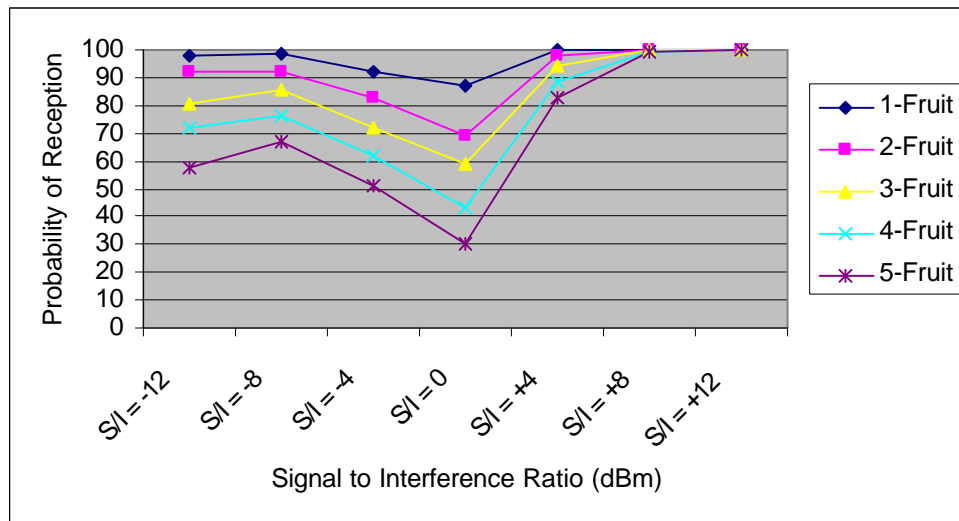


Figure 4-2 Combined Preamble and Data Block Tests with ATCRBS Fruit – Gold Standard Reception Technique

Table 4-3 shows the Combined Preamble and Data Block Test data for the Center Sample reception technique expanded to include the data for each relative amplitude. Figure 4-3 is a graphical representation of the same data.

Number of Fruit	1	2	3	4	5
S/I = -12	86.6	56.3	32.5	13.9	4.2
S/I = -8	94.2	59.8	36.7	15.5	7.1
S/I = -4	99.2	54.7	27.1	11	4.3
S/I = 0	98.3	40.2	14.4	2.6	0.8
S/I = +4	99.8	98.8	93.5	83	69.5
S/I = +8	100	100	99.8	99.7	99.6
S/I = +12	100	100	99.9	100	100
Average Reception Probability	96.87	72.83	57.7	46.53	40.79

Table 4-3 Combined Preamble and Data Block Tests with ATCRBS Fruit – Center Sample Reception Technique

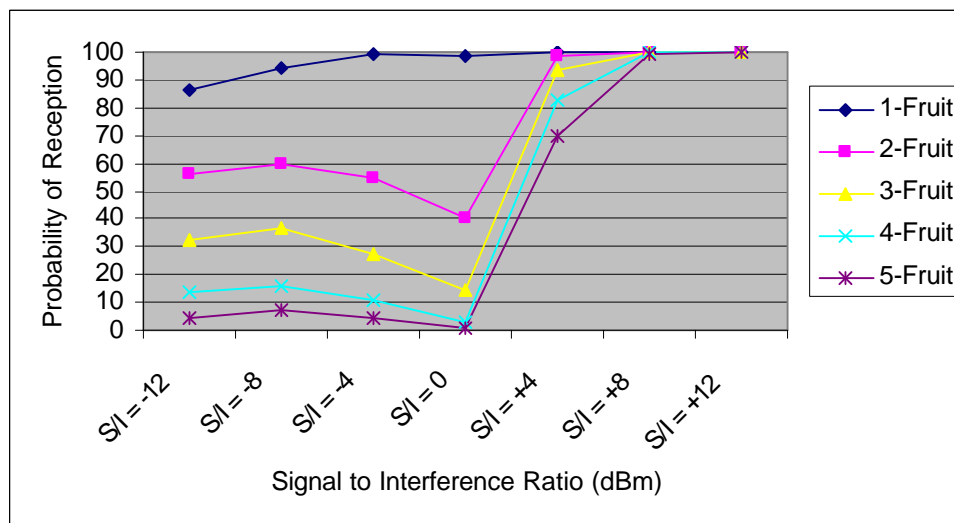


Figure 4-3 Combined Preamble and Data Block Tests with ATCRBS Fruit – Center Sample Reception Technique

Table 4-4 shows the Combined Preamble and Data Block Test data for the Multiple Sample reception technique expanded to include the data for each relative amplitude. Figure 4-4 is a graphical representation of the same data.

Number of Fruit	1	2	3	4	5
S/I = -12	99.6	96.8	84.9	69.5	49.9
S/I = -8	99.8	97.9	93.5	78.5	67.6
S/I = -4	100	98.3	92.2	81.4	67.6
S/I = 0	99.1	70.4	42.3	19.6	10.1
S/I = +4	99.8	99.3	97.5	93.8	87.8
S/I = +8	100	100	99.7	99.7	99.8
S/I = +12	100	100	99.9	100	100
Average Reception Probability	99.76	94.67	87.14	77.5	68.97

Table 4-4 Combined Preamble and Data Block Tests with ATCRBS Fruit – Multiple Sample Reception Technique

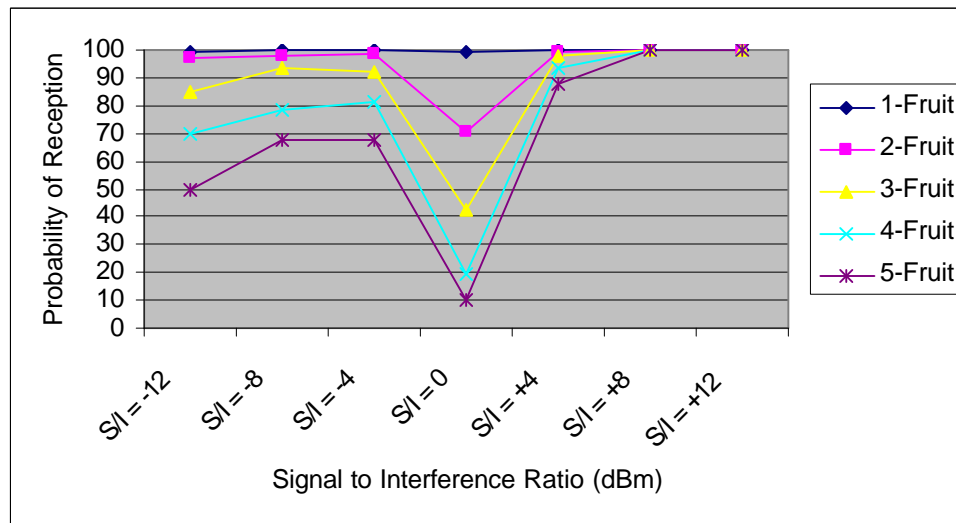


Figure 4-4 Combined Preamble and Data Block Tests with ATCRBS Fruit – Center Sample Reception Technique

## 5.0 Sample Size

One of the tests was conducted with a larger sample size to examine the effects of more samples on the data. The Combined Preamble and Data Block Test with 5 fruit was conducted with 10,000 trials per relative amplitude. Table 5-1 shows a comparison of the 10K sample run with the 1K sample results. It was noticed that there tends to be a slight variation in the results when the tests are repeated even with the same sample size presumably due to the pseudo random aspects of the test scenarios. Therefore there is no real benefit adding a decimal place to the test results by increasing the sample size. The parameter T with a value of 1000 seems quite sufficient and is recommended for use with the Enhanced Surveillance Processing Test Procedures.

Number of Fruit = 5	1000 Trials per	10000 Trials per
S/I = -12	57.6	58.26
S/I = -8	66.7	65.28
S/I = -4	51	51.98
S/I = 0	30.1	32
S/I = +4	82.8	82.56
S/I = +8	99.6	99.4
S/I = +12	100	100
Average Reception Probability	69.68571429	69.92571429

Table 5-1 Combined Preamble and Data Block Tests with ATCRBS Fruit with 1K and 10K Trials per Relative Amplitude (Gold Standard Reception Technique)